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Front cover: Splendid Ochre *Trapezites symmomus soma* perched on leaf of a dwarf bean plant. Photo Virgil Hubregtse. See page 92.

What will happen to them? Notes on some dragonfly (Odonata) species that are susceptible to the impacts of global warming-induced climate change

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Abstract
Many aquatic macroinvertebrates that require specific habitat niches are expected to relocate in response to global warming-induced climate change. For some species, relocation will not be possible because of geographic constraints or complete loss of the required habitat. Data compiled by Theischinger *et al.* (2018) was used to identify some species of Odonata at risk of extinction due to loss of habitat caused by climate change. While numerous species are at risk, this paper details only examples of habitats most likely to be impacted. Twelve species requiring these habitats are discussed. Species most at risk are those requiring alpine, sub-alpine and montane habitats. The combined effects of reduced rainfall and increased temperatures have been identified as the factors most likely to degrade these habitats catastrophically. Australia has limited alpine, sub-alpine and montane regions, and little or no alternative habitat for these species. Also, species requiring spring-fed streams are at risk due to reduced renewal of groundwater, while those that inhabit large slow-flowing rivers, particularly in the Murray Darling Basin, are likely to be impacted by algal blooms. (*The Victorian Naturalist* 138(3), 2021, 68–77)

Keywords: dragonfly, Odonata, global warming, climate change

Introduction
In 2019, Australia experienced its driest and hottest year since records began. Rainfall and temperature anomaly graphs clearly indicate global warming-induced climate change (from here on referred to as climate change) over the period 1910 to 2019 (Bureau of Meteorology [BoM] 2020). These changes result in reduced and more variable stream flow in aquatic ecosystems. The State of the Climate 2018 (BoM 2019) indicated a decline of around 11% in the April–October rainfall of south-eastern Australia since the late 1990s, and a decrease in streamflow across southern Australia. AdaptNSW (2020a) states that alpine areas and southern New South Wales (NSW) are expected to experience considerable declines in both groundwater recharge and runoff.

Twelve species of Odonata likely to be impacted at the aquatic larval stage of their lifecycle by these climate changes are detailed in this paper. Bush *et al.* (2012) analysed aquatic macroinvertebrate community data and recognised that species are expected to move to higher altitudes and latitudes where possible; however, species requiring higher altitude habitats may not have alternatives for relocation. In this paper, seven species of Odonata are recognised as vulnerable to climate change on account of their specialised alpine, sub-alpine and montane habitat requirements. Also identified are two species that rely on springs and bogs for their larval stages.

The Murray Darling Basin (MDB) has experienced numerous droughts over the years; however, the Millennium Drought (2001–2009) was the worst drought on record for south-eastern Australia (Van Dijk *et al.* 2013). Compounding the effects of droughts are competing needs for the MDB's water resources. This means that species in rivers across the MDB may be at risk of local extinction due to climate change. In this paper three species are identified as relying on large rivers for their larval habitat.

There are also some species increasing their latitudinal range as a result of climate change but these are mainly widespread Asian species

such as *Anax gibbosulus* (Kenway 2006; Sands and Burwell 2009), whereas those in decline are Gondwanan-derived. (In this sense, Australia is becoming less Australian).

Methods

Between 2004 and 2012, rivers of the MDB were sampled for aquatic macroinvertebrates under the Sustainable Rivers Audit (SRA) (Davies *et al.* 2010). The MDB extends across Australia from Queensland through NSW, Victoria, and into South Australia. The SRA applied a random sampling design stratified by altitude zones. The MDB was divided into 23 valleys and within each valley a defined stream network was mapped. This network was divided into altitudinal zones, with boundaries at 200 m ASL, 400 m ASL and 700 m ASL.

Thirty-five locations within each valley were sampled for macroinvertebrates, with the number of locations per zone proportional to the defined stream length within that zone (Davies *et al.* 2010). Sampling was conducted each spring and autumn according to each state's AusRivAS protocols and sampling methods developed in the National River Health Program in 1994 (Davies 2000). Macroinvertebrate sampling sites extended a minimum of 100 m along each stream and included samples of edge habitats and, if present, riffle habitats. The macroinvertebrates collected in the audit samples were identified to taxonomic family level; however, Gunther Theischinger identified Odonata to species level with the aid of published keys, e.g. Hawking and Theischinger (1999); Theischinger (2000, 2001, 2002, 2007) Theischinger and Endersby (2009).

The SRA was not a dragonfly or biodiversity study; it was designed to be a rapid river health assessment program. The randomly selected sites were not sampled during particular seasons nor necessarily in weather situations/ conditions selected to maximise the collection of odonate diversity. Despite these limitations, odonates were collected at numerous sites; however, the species collected during the SRA program represent only a fraction of the species now recorded from the basin.

The SRA dragonfly data were compiled into a book titled *Dragonflies (Odonata) of the Murray-Darling Basin* (Theischinger *et al.* 2018). In addition to the MDB data, the book contains information on the distribution of odonates that occur outside the basin, ecological notes on the species, and their habitat requirements. A combination of the book's distribution maps, species' current conservation status and habitat requirements, as well as predicted climate change species distribution scenarios (provided by Alex Bush and included in the book), was used to select those odonate species the authors considered at risk of extinction due to climate change and/or climate change-related situations.

Results

From the Odonata species detailed in the book, species identified as most prone to extinction (especially those listed as Vulnerable on the IUCN Red List) were those dependent on high altitude cool-flowing streams; those requiring spring-fed streams or seepages and bogs; and those dependent on the water quality of large slow-flowing rivers.

Aeshnidae: *Austroaeschna flavomaculata* (Figs 1 and 2) is the only truly alpine species of odonate in Australia. It has a localised distribution in the southern alps of NSW and Victoria. This species requires alpine trickles and seepages as habitat, and these water sources are vulnerable to climate change for two reasons. Firstly, with reduced rainfall, trickles and run-off water tend to disappear for much of the year. Secondly, increased temperatures will greatly reduce the extent of alpine areas available, leaving this species with nowhere to go.

As a result of climate change, the closely related *Austroaeschna multipunctata*, which coexists with *A. flavomaculata* in the same habitats in some places, may replace the latter species at high altitudes.

Aeshnidae: *Austroaeschna inermis* (Figs 3 and 4) is restricted to montane rivers and streams of south-eastern NSW and northern Victoria. In the MDB, it was collected from sites with altitudes ranging from 270 to 1430 m ASL, and generally within 40 km of the stream's source. The water at the collection sites had low conductivity and turbidity and a high level of dissolved oxygen, typical of montane streams.

Under climate change scenarios, these habitats would be impacted by reduced and less frequent flow and higher water temperatures,

Fig. 1. Male *Austroaeschna flavomaculata.*

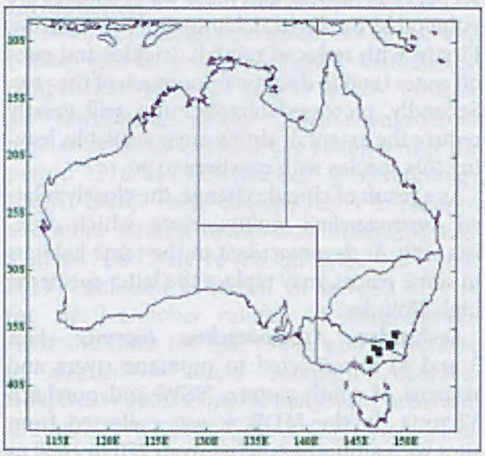

Fig. 2. Distribution of *Austroaeschna flavomaculata* sites.

meaning that this species also would have nowhere to go. As a result of climate change the apparently less cold-adapted but closely related *Austraoaeschna unicornis* could outcompete and replace *A. inermis* in its particular original habitats.

Fig. 3. Male *Austroaeschna inermis.*

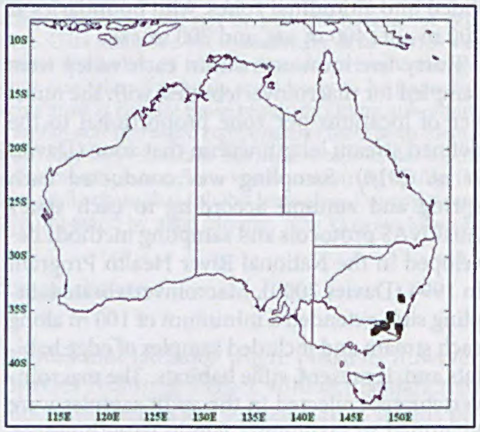

Fig. 4. Distribution of *Austroaeschna inermis* sites.

Aeshnidae: *Austroaeschna multipunctata* (Figs 5 and 6) is another species restricted to small montane streams of southern NSW and Victoria. The collection sites within the basin were all within 40 km of the stream's source at altitudes ranging from 210 to 1500 m ASL. Water quality varied across sites, indicating that the species tolerates a range of temperatures, conductivities and turbidities. However, no aquatic species can live without water, and reduced rainfall is most likely to impact small montane streams. With ongoing climate change this species may, like *A. flavomaculata,* have nowhere to go.

Aeshnidae: *Austroaeschna subapicalis* (Figs 7 and 8) inhabits montane streams in NSW and Victoria. Water quality data from collection sites in the basin indicated that this species prefers low conductivity, low turbidity, a high level of dissolved oxygen and neutral pH.

Fig. 5. Male *Austroaeschna multipunctata.*

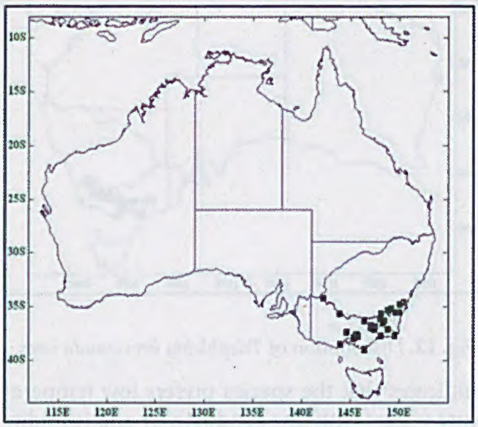

Fig. 6. Distribution of *Austroaeschna multipunctata* sites.

Sites in the basin were all within 20 km of the stream's source and at altitudes ranging from 270 to 1150 m ASL. Reduced rainfall is likely to impact the habitat of this species severely.

Austropetaliidae: *Austropetalia tonyana* (Figs 9 and 10) has been recorded from only 17 locations in south-eastern Australia. It inhabits trickles, sphagnum swamps and splash zones of waterfalls. *Austropetalia tonyana* is listed as Near Threatened in the IUCN Red List. It is at risk of habitat loss caused by climate change because reduced rainfall scenarios will dry out sphagnum swamps and reduce the availability

Fig. 7. Male *Austroaeschna subapicalis.*

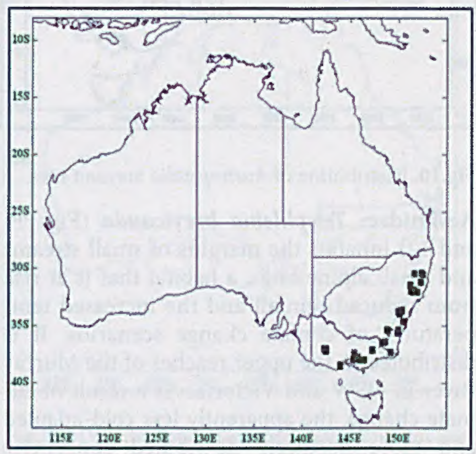

Fig. 8. Distribution of *Austroaeschna subapicalis* sites.

of trickles and waterfalls. Even inside protected areas, excessive tourist numbers or ill-advised development of tourist facilities could present threats, and collection of specimens by people other than scientists also poses a threat to this rare and extremely attractive species. Threats such as forest fires and increased frequency of droughts go hand in hand with climate change.

Fig. 9. Female *Austropetalia tonyana*.

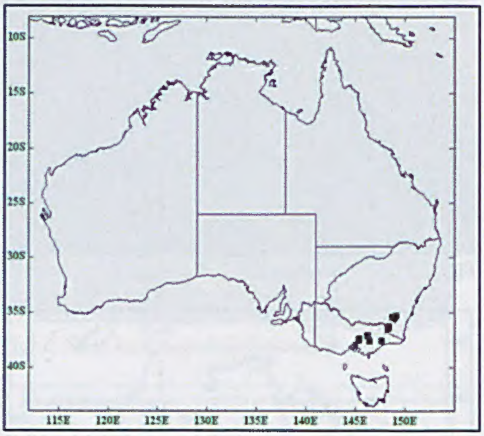

Fig.10. Distribution of *Austropetalia tonyana* sites.

Fig. 11. Male *Telephlebia brevicauda*.

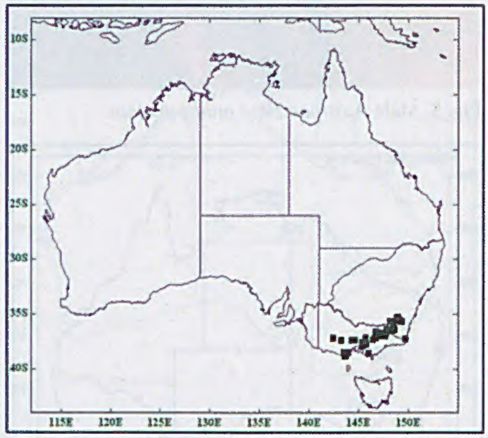

Fig. 12. Distribution of *Telephlebia brevicauda* sites.

Aeshnidae: *Telephlebia brevicauda* (Figs 11 and 12) inhabits the margins of small streams and small alpine bogs, a habitat that is at risk from reduced rainfall and the increased temperatures of climate change scenarios. It is distributed in the upper reaches of the Murray River in NSW and Victoria. As a result of climate change, the apparently less cold-adapted and more northerly distributed congeneric species *Telephlebia godeffroyi* could outcompete and replace *T. brevicauda* in its particular original habitats.

Synthemistidae: *Eusynthemis guttata* (Figs 13 and 14) inhabits alpine and montane streams in south-eastern NSW and Victoria. Those sites in the basin where the species was collected were within 25 km of the stream source and at altitudes ranging from 210 to 1390 m ASL. The water quality of the collection sites in the basin indicates that the species prefers low temperature waters with low conductivity and turbidity and a high level of dissolved oxygen. This species' habitat is likely to be impacted by reduced rainfall and increased temperatures of climate change scenarios. *Eusynthemis tillyardi*, probably its sister species, now mainly more northerly distributed and presumably less cold-adapted, may invade the original habitats occupied by *E. guttata* and outcompete and replace it.

Argiolestidae: *Griseargiolestes fontanus* (Figs 15 and 16) inhabits streams near springs and was collected only once from the MDB. AdaptNSW (2020a) states that large changes are projected to occur in groundwater recharge and surface runoff by 2070. This may cause spring flow to become more variable. Some populations of this species are close to human

Fig. 13. Female *Eusynthemis guttata.*

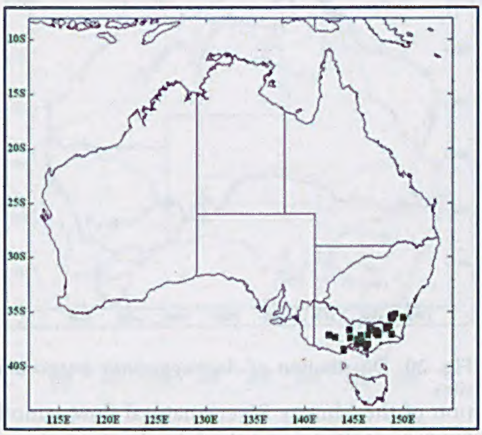

Fig. 14. Distribution of *Eusynthemis guttata* sites.

population centres and therefore vulnerable to development-related threats. Residential and commercial development in these urban areas is ongoing.

Coenagrionidae: ***Caliagrion billinghursti*** (Figs. 17 and 18) inhabits sluggish rivers, riverine pools, lakes and ponds. This species is listed as Vulnerable on the IUCN Red List. Its habitats are at risk of impacts from drought, variability of flows and poor water quality. During and since the Millennium Drought, there have been significant algal blooms in the MDB (MDB 2020a), which have caused major

Fig. 15. Female *Griseargiolestes fontanus.*

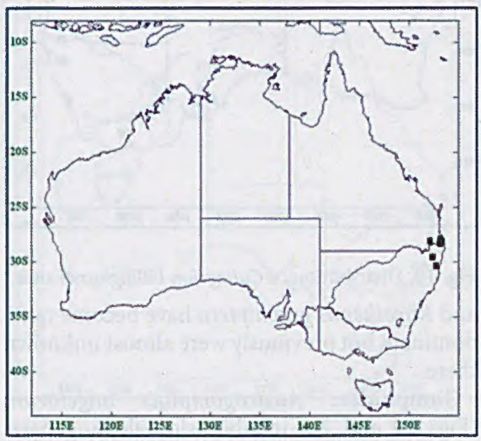

Fig. 16. Distribution of *Griseargiolestes fontanus* sites.

fish kills (MDB 2020b). Reduced flows and associated algal blooms in one of the sites where *C. billinghursti* is known, in suburban Sydney, may have caused significant decline, if not disappearance, of *Austrocordulia leonardi*. This species is listed as Endangered under the NSW Fisheries Act. It is a dragonfly of uncertain family placement, and often co-occurs with *C. billinghursti*. In contrast, *Zyxomma elgneri*

Fig. 17. Male *Caliagrion billinghursti* feeding.

Fig. 19. Male *Austrogomphus angelorum.*

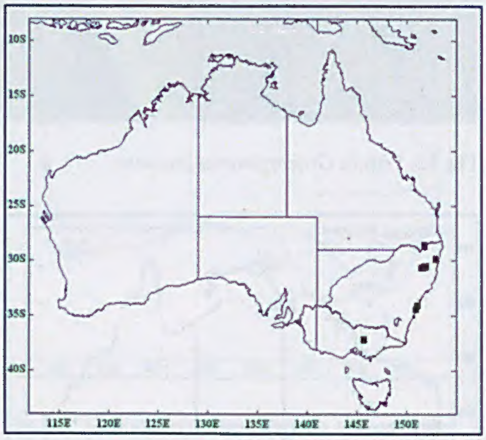

Fig. 18. Distribution of *Caliagrion billinghursti* sites.

Fig. 20. Distribution of *Austrogomphus angelorum* sites.

and *Rhyothemis graphiptera* have become quite dominant but previously were almost unknown there.

Gomphidae: *Austrogomphus angelorum* (Figs 19 and 20) inhabits slow-flowing parts of the Murray River. The species is apparently very rare (Hawking and Theischinger 2004; Richter and Endersby 2019). It is very important to ascertain the continuing survival of *Austrogomphus angelorum,* as it was neither collected since the 1960s, nor during the SRA program. The Murray River suffers reduced flows during drought as a result of extraction of water for irrigation. These combined impacts have caused large algal blooms that have killed fish and, presumably, large aquatic macroinvertebrates such as *A. angelorum*. The disruption of the Murray River's natural flow, runoff from agriculture, and the introduction of pest species of fish such as the European carp have led to serious environmental damage along the river's length, with concerns that the river will become unusably saline (for irrigation) in the medium to long term.

Dragonfly genera of uncertain family placement: *Apocordulia macrops* (Figs 21 and 22) inhabits large rivers, a habitat that is frequently sampled; however, records show there have been very few collections of this species. Collection sites in the MDB indicate that it is found at altitudes below 240 m ASL and more than 100 km from the source of the rivers from which specimens have been collected. As with the previous two species, these large westward-

Fig. 21. Female *Apocordulia macrops.*

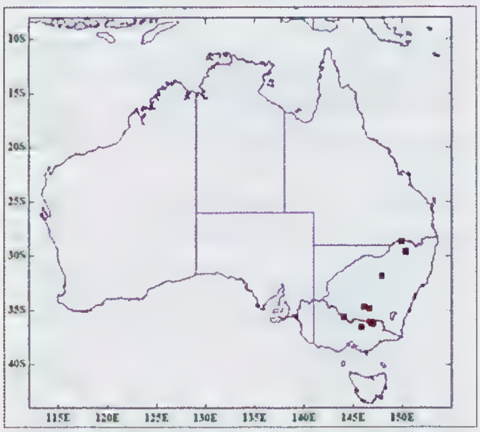

Fig. 22. Distribution of *Apocordulia macrops* sites.

flowing rivers of the MDB suffer impacts that place the habitat of *Apocordulia macrops* at risk.

Petaluridae: *Petalura gigantea* (Figs 23 and 24) inhabits boggy seepages and swamps at altitudes from 0 to 1150 m, and is listed as Endangered in NSW. Its habitat is at risk from both climate change and mining. Disturbances, including mining, groundwater extraction, livestock damage and exposure to pesticides, have diminished or degraded larval habitat and led to declining populations.

Discussion and conclusions

Bush *et al.* (2014) used an ensemble of species distribution models to predict the

Fig. 23. Male and female *Petalura gigantea* pairing.

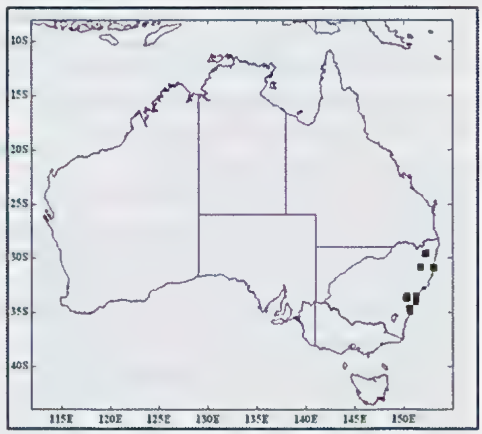

Fig. 24. Distribution of *Petalura gigantea* sites.

distribution of 270 species of Australian Odonata, continent-wide at the sub-catchment scale, and for both current and future climates using two emissions scenarios for each of 2055 and 2085. They found that the proportion of species at risk of extinction varied between 7% and 17% from 2055 to 2085. A further 3–17% of species were projected to be at high risk of extinction due to declines that did not require range shifts. We found twelve species were identified as

examples of Odonata at risk of extinction due to climate change impacting their habitat requirements.

Alpine and sub-alpine species

The Adapt climate projections for 2060–2079 (AdaptNSW 2020a) show that average temperatures could rise by up to 2° C and rainfall diminish by up to 10% across alpine and subalpine regions by 2079. These changes are likely to result in the loss of, or great reduction in, available habitat for seven dragonfly species, namely *Austroaeschna flavomaculata, Austroaeschna inermis, Austroaeschna multipunctata, Austroaeschna subapicalis, Austropetalia tonyana, Telephlebia brevicauda* and *Eusynthemis guttata.* This potential loss of habitat is likely to be compounded by recreational activities (mainly skiing), construction of infrastructure for recreation, and damage to streams by feral animals.

It is likely that the habitat of these seven species of dragonfly will be reduced or lost under current climate change scenarios. With only relatively small areas of alpine, sub-alpine and montane habitat remaining in Australia, there is nowhere else for these species to go.

Groundwater dependent species

The CSIRO summary report (Barron *et al.* 2011) investigated climate change impact on groundwater resources in Australia. The study found that, for the median future climate (up to 2050), 79% of Australia is projected to experience a reduction in recharge, with 27% of this area showing a projected reduction of greater than 20%. They note that this is the continent-wide assessment and, at the regional and local scale, groundwater recharge will depend on aquifer type, rainfall amount and seasonality, and land use. The NSW Government Adapt website indicates that, by 2070, groundwater recharge is likely to become more seasonally variable (AdaptNSW 2020b).

Dragonfly species that rely on spring-fed streams, such as *Griseargiolestes fontanus,* may be at risk of climate change impacts to groundwater recharge, seasonality and changes to local land use.

Species at risk of toxic water quality

From March to May in 2009, a major blue-green algal bloom extended some 1000 km along the Murray River on the border of NSW and Victoria downstream from Hume Dam. Again, in 2016, an algal bloom that started in Lake Hume spread 700 km down the Murray River (MDBA 2020a). The de-oxygenation of river water caused by algal blooms can cause fish kills. Low flows, higher water temperatures and input of ash from bushfires can lead to water de-oxygenation and algal blooms (MDBA 2020a). Blackwater events, where flood follows drought and washes debris into rivers, can also cause fish deaths (MDBA 2020b).

The combination of warmer temperatures, increased frequency and intensity of fires, lower flows and increased nutrients are likely to contribute to more frequent and more extensive algal blooms in our large rivers such as the Murray. Extensive fish kills caused by water de-oxygenation and blackwater events have been occurring for some years. The dragonflies *Caliagrion billinghursti, Austrogomphus angelorum* and *Apocordulia macrops* are also at risk from these toxic conditions.

Upland swamp dependent species

Predicted changes in the amount and seasonality of rainfall will put swamps and seepages at risk of drying, at least for part of the year. 'Coastal Upland Swamp in the Sydney Basin Bioregion' is listed as an Endangered Ecological Community under the *Biodiversity Conservation Act 2016.* Threats to the swamp community, as listed on the determination, include: alteration of habitat including hydrology following subsidence due to long wall mining; changes in moisture levels associated with climate change; alteration of fire regimes; clearing, disturbance, runoff and sedimentation associated with infrastructure, quarries, surface facilities and recreational facilities; localised disturbance associated with unauthorised recreational activities including access by vehicles, trailbikes and horses; browsing and soil disturbance by deer and pigs; loss of diversity from an over-abundance of large shrubs; and infection of native plants by *Phytophthora cinnamomi* (Office of Environment and Heritage 2020). These swamps are the habitat of the *Petalura gigantea* larvae. Baird (2014) and Baird and Burgon (2016) found *P. gigantea* to be an obligate,

groundwater-dependent, mire-dwelling species with well-maintained and sometimes complex burrows.

The larval habitat of the dragonfly *Petalura gigantea* is at risk from the effects of climate change such as increased fire risk and changes in soil moisture. As an obligate groundwater dependent species, impacts to its habitat will leave *P. gigantea* with nowhere to go.

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The photographs of dragonflies and maps of distribution in this paper, with the exception of the map of *Apocordulia macrops*, which has been somewhat updated by I Endersby (Montmorency, Australia), are taken from Theischinger *et al.* (2018). The sources of maps and photos are acknowledged in this book.

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Historical reports of quolls in Victoria's south-west

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Abstract
The Eastern Quoll *Dasyurus viverrinus* is now extinct on mainland Australia, but was once common in south-western Victoria. It was persecuted by landholders for its predation of poultry, but also suffered dramatic declines in population through an unknown disease from about 140 years ago. Eastern Quolls were also considered significant predators of young European Rabbits *Oryctolagus cuniculus*. The Spot-tailed Quoll *D. maculatus* was historically widespread though uncommon in south-western Victoria, but now is confined there to only a couple of sites. (*The Victorian Naturalist* **138**(3), 2021, 78–85)

Keywords: quolls, south-western Victoria, historical reports

Introduction

Quolls are the largest, native, carnivorous marsupials on the Australian mainland. Three species are known from Victoria (Menkhorst 1995). The Eastern Quoll *Dasyurus viverrinus* (Fig. 1), now absent from the state, and the larger Spot-tailed or Tiger Quoll *D. maculatus* (Fig. 2) have been the most numerous. A third species, the Western Quoll *D. geoffroii* (Fig. 3), was collected during the Blandowski expedition in 1857, along the banks of the Murray River near Mildura (Wakefield 1966). This species is now confined to the south-western corner of Western Australia, a massive decline in its range since European settlement (Menkhorst 1995).

Quolls are very attractive marsupials, about the size of a Cat *Felis catus*—in fact Eastern Quolls were commonly called 'native cats' and

Fig. 2. Spot-tailed or Tiger Quoll *Dasyurus maculatus.* Image taken from Gould J (1974) *Australian marsupials and monotremes,* p. 111.

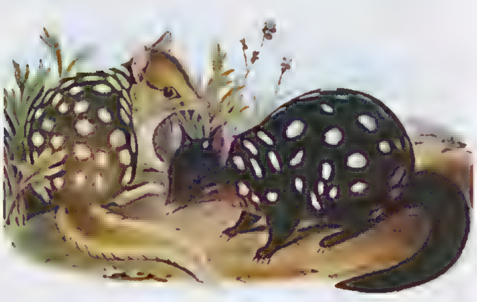

Fig. 1. Eastern Quoll *Dasyurus viverrinus* showing the two colour forms. Image taken from Gould J (1974) *Australian marsupials and monotremes,* p. 113.

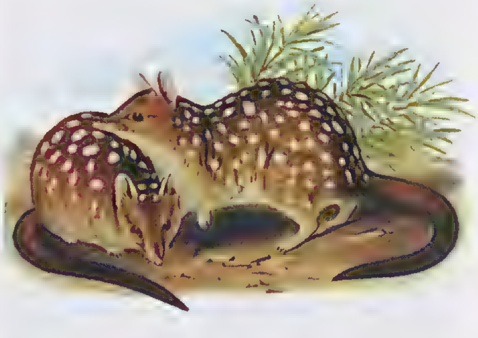

Fig. 3. Western Quoll *Dasyurus geoffroii.* Image taken from Gould J (1974) *Australian marsupials and monotremes,* p. 115.

Fig. 4. Map of Victoria, showing main sites mentioned in text.

Spot-tailed Quolls were called 'tiger cats' by early settlers (Peacock and Abbott 2013). Abbott's (2013) extensive searches of historical sources found over 400 Aboriginal names for Australian quoll species and recommended adoption of Chuditch (*D. geoffroii*), Bindjulang (*D. maculatus*) and Luaner (*D. viverrinus*) as vernaculars instead of Western, Spot-tailed and Eastern Quolls.

Quolls were once quite common in a wide range of habitats in Victoria (except for the Mallee), but their numbers suffered dramatically in the late 1800s and early 1900s, probably as a result of disease that also affected several other marsupial species (Menkhorst 1995; Ford 2014; Peacock and Abbott 2014).

Here, I present historical reports of quolls in south-western Victoria, many hitherto unreported in modern times. The reports were obtained from old newspaper and other reports. I also document descriptions of the species' predatory interactions with Domestic Chickens *Gallus gallus domesticus* and European Rabbits *Oryctolagus cuniculus*.

Quolls in Victoria today

The Spot-tailed Quoll was once widespread in southern and eastern Victoria, but is now confined to the Eastern Highlands, East Gippsland, the Otway Ranges and Budj-Bim National Park (Menkhorst 1995). In 2013, one was photographed in the Grampians, which is good news indeed (Australian Broadcasting Corporation [ABC] 2013). The south-eastern Australian mainland population is classified as Endangered, by both the Victorian (2013, Fig. 4); and Commonwealth Government (2020).

The Eastern Quoll was once widespread across Victoria and in some locations occurred in high numbers, but by the late 1950s it had become extinct in this state. Seebeck (1984) noted that, even by 1923, it was found in only three Victorian sites: Alvie-Dreeite on the east bank of Lake Corangamite, Studley Park in Melbourne and Gelantipy in East Gippsland. It is considered Endangered by the Commonwealth (Australian Government undated).

Quolls in Victoria's south-west

Samuel Hannaford described marsupials he encountered while working in Warrnambool

from 1854 and recorded these in his delightful little book (Hannaford 1860), which describes the natural history of the sea and riverbanks of Melbourne, Warrnambool and Geelong. The marsupials mentioned inhabiting the Hopkins River banks, south of the Hopkins Falls in Warrnambool, include 'flying squirrels' [gliders, probably Sugar Glider *Petaurus breviceps*], 'opossums' (possums), wombats, Koalas *Phascolarctos cinereus* and the 'Long-snouted Bandicoot *Perameles nasuta*' (Long-nosed Bandicoot). Closer to the sea, Hannaford noted 'herds of Wallabies frequent this neighbourhood' and 'the tracks of the Native Cat are everywhere conspicuous' (Hannaford 1860: 115).

Old newspapers are an excellent source of information on natural history. Peacock and Abbott (2013) searched for items about native cats or quolls and their interactions with Rabbits in Australia. A report in 1856 stated: 'Found five chickens killed this morning. I suppose by the wild cats.' (McCorkell 1967: 26). Peacock and Abbott (2013) believe the species to which this referred was the Eastern Quoll. The site was a farm in Yangery, 8 km west of Warrnambool.

In 1856, a writer also recorded native cats in North Warrnambool in what was then Dooley's paddock, along with the 'destructive parrot, and kangaroo [and] the valueless wombat opossum' (Anon 1856 p. 3).

The Atlas of Living Australia (ALA) (2021a) records one 'sub-fossil' record (bones) of *D. viverrinus* in Warrnambool, just north of McMeekin Rd in what is now the industrial estate. The record was from January 1900 and is the only record for either quoll species in Warrnambool. The ALA (2021a, b) also has records, supposedly provided by Andrew Bennett, of historic sightings of both Eastern Quolls and Spot-tailed Quolls near Woolsthorpe from 1840. This was based on Bennett (1982) in which the author cited James Dawson, a squatter who settled at Kangatong station near Hawkesdale (Dawson 1881). The local Aborigines called the Eastern Quoll 'Dasyure, brown and spotted native cat' and the Spot-tailed Quoll 'Dasyure, tiger cat' (Bennett, 1982: 232) and both species then lived in the Hawkesdale area. The next report of Eastern Quoll closest to Warrnambool in the Atlas is in the Stony Rises, in 1931 (ALA 2021a).

Were there any other historical records of quolls in the region? Seebeck (1984) tells of an interesting find of nine mummified carcasses of quolls under the woolshed floor of a property at Darlington in 1980. The woolshed had been built in 1855 and the property owner had no idea when the quolls might have died. Seebeck (1984: 41) dryly notes 'perhaps there are many such caches of Eastern Quoll remains beneath Western District buildings—it would certainly be worth the search.'

Bennett (1990) reported on two residents of the south-west recalling native cats (believed to be Eastern Quolls) around 1920 at Framlingham Forest and Terang Lake.

Atlas of Living Australia (2021b) records of the Spot-tailed Quoll in the south-west are more numerous. Thus, in 1970, a *D. maculatus* was found 32 km north of Port Fairy, on the Hamilton Road and presented to the Museum of Victoria. Similarly, in 1964 the Museum received a specimen found at Bessiebelle, and another in 1967 from 16 km SW of Macarthur. In 1966, a Spot-tailed Quoll was found 12.8 km west of Heywood, near Deadwood Swamp.

Just how common were quolls?

Most early reports suggested quolls (especially the Eastern Quoll) were very common in the south-west. Rolls (1969) tells of an 1867 sporting magazine article reporting that 622 native cats were shot at Barwon Park, Winchelsea in 1866. Earlier, in the 1850s, some 600 were shot in one night around Wando Vale, north of Casterton (Nelson 1968).

Seebeck (1984: 40) reported on information provided by a correspondent in 1934 to the then Fisheries and Game Department about the abundance of quolls in the Warrnambool area:

> ... 55 years ago I was offered a bonus of ½d a scalp ... to trap these native cats ... but I caught so many that the contract was ended.

In 1886, the *Warrnambool Standard* carried a note under the heading 'Ellerslie News' that the district was overrun with native cats (Anon 1886a).

They were also common in parts of the Wimmera. It was reported in 1895 that the Horsham Police Court was told by a rabbit trapper that 'He saw a few burrows and some fresh tracks of rabbits and others of native cats, with which it

was infested.' (Anon 1895: 3). In the Stony Rises, Cromelin (1886: 31) noted native cats 'could be found under every stone.'

The Spot-tailed Quoll, however, seemed less numerous and less likely to take poultry, but lasted in the south-west longer than the Eastern Quoll. In western Victoria its current distribution is confined to the Otway Ranges, the Grampians and Budj-Bim National Park.

Quolls and Domestic Chickens

There are many newspaper reports of large numbers of quolls and how they preyed on Domestic Chickens in the south-west. Most articles concern the Eastern Quoll. For example, correspondent BEC (1944: 3) reported in his regular 'Nature Notes' column in the *Portland Guardian*:

> J.C. FitzGerald writes: Your notes on native cats takes my memory back a long way. I haven't seen one for over 40 years. In the 70's a plague of them, similar to present day mouse plagues, swept over the country. They were in thousands and spent the day in hollow logs, under out-buildings, or anywhere they could get shelter. Any fowls not securely shut up were soon mopped up, and they must have taken a tremendous toll of ground birds, which were far more numerous then than they are now. I can't say how long the plague lasted. The years are very long when one is young, but it probably was not long before they died out to a great extent ... They were sleek and fat, with good skins when they arrived, but after some time got thin and mangy, with a lot of ticks of a slate-grey colour on them, which I always thought may have had something to do with their poor condition. There were no rabbits when the native cat army arrived. I have often thought that had there been they might have survived longer. Why they were called cats I do not know, as they are not a bit like a cat. The long, pointed nose for one thing makes them unlike any cat. The larger tiger cat was not nearly so numerous as the smaller kind, and though I have seen plenty of them, I didn't know until I read Mr. Stuchbery's comments that they, like the smaller kind, were of two colours. I have only seen the grey and he is quite right about them putting up a good fight, and it took a game terrier to kill one.

Similarly, in the same newspaper, Cundy (1936: 1) wrote:

> Now for the native cats, which are at present very rare, but at one time were classed as a nuisance. Their favourite sport was raiding hen roosts at night, and it was a common experience for householders to lie disturbed by a commotion in the fowl pens at some unwelcome hour. Box traps were one method of dealing with the pests. There were two varieties in colour, but they were actually the one breed ... Native cats, like the wallaby, died out in hundreds from some disease that broke out among them. Many people said that the laying of poison for the rabbits was the cause, but they died before poison laying became general. So much for the native cat, whose, botanical [sic] name was Daysure or Dasyure, which I have seen spelled both ways. There was also another and larger variety known as the Tiger Cat. He was about three times the size of his smaller brethren, and it took a really strong dog to kill one of them, but they were never very numerous.

In the Naringal area some 10 km east of Warrnambool, Goldstraw (1937) recalled fowls being attacked by 'tiger' or 'native cats' during the night in the 1890s.

In South Dreeite (east of Lake Corangamite), also, it had been noted that native cats were playing havoc with soldier settlers' fowls and chickens (Anon 1926). In 1934 a writer in the same area reflected on the large number of quolls in years gone by and the effects they had on poultry (Carter 1934: 5):

> It is an unusual experience to meet with native cats nowadays, even in the more remote bush. They were, at one time, a formidable pest to poultry-breeders, but something came along and cleared them out. Some have argued that they are still in the bush, but that they find less risky prey in the rabbits, but it is doubtful, as they are never seen by trappers.

In Hamilton, in 1870, a newspaper correspondent (Anon 1870: 2) observed that native fauna was being driven from towns as a result of habitat loss, except for quolls:

> ... for the native cats seem to have effected a lodgment in the town, where they breed in the same way as the domestic rat. In wooden houses especially, the native cats, are particularly troublesome, locating themselves beneath the flooring or behind the wainscotting, and scampering about between the roofs and ceilings. The vermin are very destructive to hen-roosts, and in some parts of the town it is impossible to keep fowls, owing to the depredations of the native cats.'

Quolls and European Rabbits

The disease mentioned beforehand apparently reduced quoll numbers dramatically in the 1870s to 1880s. Quolls were also poisoned by landholders concerned the marsupial predators took their Chickens, and when the European Red Fox *Vulpes vulpes* was introduced in 1874, quoll numbers were reduced even further (Peacock and Abbott 2013).

There are many possible causes for the decline in quolls from very high numbers in some locations. These are not mutually exclusive. Peacock and Abbott (2014) investigated the declines in number and believed pathogens, including those carried by ectoparasites such as ticks, would have been one such cause. As well, evidence was found of predation by introduced Cats *Felis Catus* and Red Foxes. There were also reports of quolls choking on Rabbit fur.

Quolls were once so common that it is believed their predation of young Rabbits prevented the eruption of Rabbit populations in Victoria (Peacock and Abbott 2013). These authors have found evidence of over 90 releases of the European Rabbit before the 1859 release by Thomas Austin at Barwon Park (Winchelsea). It was this release that experts believed was one of the main sources of the population establishment and subsequent spread to many parts of Australia. However, there were several other releases about the same time that led to large populations of Rabbits (Rolls 1969); Thomas Austin thus cannot be solely blamed for the plague of bunnies!

There were many early reports in western Victoria supporting the claim that quolls preyed especially on young Rabbits. A letter to the editor of *The Australasian* from a reader in Balmoral (Hayman 1892: 8) stated:

> Data provided demonstrate that native cats eat rabbits caught in traps. These traps also catch native cats. Tiger cats are also caught in these 'abominable' traps, with 3 of this species caught in the last 2 weeks.

Across the border in Mt Gambier, a correspondent warned in 1884 that though Rabbits were not yet in the huge numbers found elsewhere in the state:

> … it would not be wise to assume that we shall always enjoy this immunity. No doubt large areas of the South-East are unsuitable as a habitat for the vermin. Much of it is liable to flooding, a good deal more of it is composed of loose soil not adapted for their burrows, while the most fertile is so subdivided that they would find their quarters uncommonly warm. Besides all this they have an inveterate enemy in the native cat, still pretty numerous. But despite these favourable conditions for keeping them in check the plague is not a thing to be trifled with. The rabbit, like the British race, has a peculiar knack of adapting itself to new conditions; and if it is allowed time and opportunity, we should not be surprised to find it developing into an animal that would thrive and multiply amid our swamps and on our heaths.' (Anon 1884: 2).

In the same year, a correspondent named The Vagabond (1884: 4) described having seen a flyer in Euston, on the banks of the Murray River:

> Outside the police station we read a proclamation from the Colonial Secretary of New South Wales threatening pains and penalties for the destruction of the iguana, the native cat, the mongoose, the tiger cat, the ferret, and the domestic cat, these being protected as natural enemies to the rabbit.

I think today's naturalists would be horrified to see the suggestion that we conserve mongeese, ferrets and Feral Cats because they are predators of Rabbits. Even in 1886, a Casterton resident thought it was ridiculous to even think of introducing stoats, mongeese and weasels to prey on Rabbits (Venator 1887). Nevertheless, over 1000 mongeese were indeed released in New South Wales, Victoria and South Australia to control Rabbits, mainly in 1883 and 1884 (Peacock and Abbott 2010). Fortunately, the releases were unsuccessful.

Even attempts to breed Rabbits failed because of predation by Eastern Quolls. An anonymous observer in the early 1900s (cited in Ford 2014: 58) wrote:

> From 1820 to 1869 probably not a year passed but some adventurous man or boy tried to turn [rabbits] out and breed them; but all met with the same fate – extermination by the native cat.

The following report (Anon 1885: 3) suggests quolls may even have been captured in large numbers and released elsewhere to help control Rabbits:

> A report of their experience of native cats as rabbit exterminators has been furnished to the Government … [in] Narrandera, New South Wales. About 700 native cats were released in sound, healthy condition. Most of the animals were obtained from about Goulburn, Bungendore and Queanbeyan, the total cost of the [operation] is much less than it takes to keep one man rabbitting for a year, and the experimenters are certain that more good has been done than 1500 would have effected, by other means. There are two places on the run where large rocks abound with holes, the best-known cover for rabbits, in which they had fairly established themselves. A large number of the native cats were put among these rocks, and for a long time it was feared that they would be a disappointment, as the rabbiters caught as many as before, and the increase in the number killed continued. About three months later an inspection

> showed indications such as scarcity of scratches, deserted burrows, and fewer fresh used ones; that they had been completely hunted out of the rocks, where there were cat tracks, but no rabbits. It was supposed that the cats assisted the hunters by chasing the rabbits out of the rocky places, where they could not be got at.

In 1921, a Perth newspaper published a report of a book written by James Matthews, a former officer of the Vermin Destruction Board of the Victorian Lands Department. The article noted that Mr Matthews claimed that originally native cats 'prevented the early multiplication of the rabbits, but that in time the rabbits increased in numbers and apparently drove out the cats from certain districts.' (Anon 1921: 7). Of course, by 1921 the disease in and persecution of quolls had reduced their numbers significantly so it was not surprising they could no longer limit Rabbit numbers. However, it would be unlikely that Rabbits would have driven the quolls away!

Not everyone in south-west Victria agreed that quolls help regulate Rabbit nubers. An article in *The Australasian* (Bruni 1886: 11) about Rabbits in the West- ern District, was skeptical of this effectiveness:

> It is a curious fact connected with the extermination of the rabbits in the Western District, that no sooner was the country free from rabbits than native cats appeared in immense numbers. The theory that the native cats and hawks assist in destroying the rabbits appears to be without much foundation. It has been proved on many occasions, both in Tasmania and Victoria, that rabbits will invade and establish themselves in a country in which native cats and tiger cats abound, and that as the rabbits increase the native cats disappear. I believe more rabbits have been killed in one drive on Mount Fyans than all the native cats in Victoria would destroy in a year. After many years' experience in rabbit-killing, Mr. W. Cumming is now firmly convinced that, unless their homes are destroyed, it is hopeless to attempt to exterminate the rabbits in a country where they find so safe a shelter on every hand as in the Stony Rises. Protecting hawks and native vermin is useless, and only adds other pests to the already overwhelming one of the rabbit. To be effective, the work should be carried out simultaneously by all the owners of land in the rabbit-infested districts.

In a later issue of the same newspaper, a letter to the editor described how Rabbits and native cats lived in harmony together in burrows in Casterton (Venator 1887). In Horsham, a note also described co-habitation of a native cat, a Domestic Cat and a Rabbit. (Anon 1886b).

Another letter writer from Camperdown (Willingham 1885: 3) also disputed the idea that native cats controlled Rabbit numbers:

> … we hear from Cobden of a number of rabbits and also a number of native cats occupying the same cover ... I agree with and endorse your view that the cat is not a natural enemy of the rabbit, and … it is no uncommon circumstance for animals of both classes to occupy the same place of concealment, as I have on several occasions when digging for rabbits, found a cat in the same burrow apparently quite regardless of each other's presence. No, the cat has no partiality for the rabbit other than socially …

The decline in quoll numbers, however, was cause for alarm from some early writers. David Fleay was a strong supporter of the conservation of native fauna. In 1931, he trapped 16 Eastern Quolls at South Dreeite, where they lived in the stone fences and rocky outcrops, and set up a captive breeding program at the Melbourne Zoo (Seebeck 1984). This might have been one of the earliest captive breeding programs of the kind that are now so important at the Zoo, which has a strong conservation function.

Fleay also wrote extensively on the plight of quolls. In 1934, for instance, he wrote an article in *The Argus*, noting: 'Nevertheless such an interesting native animal which is of value as a destroyer of young rabbits, rats, and mice, should not be allowed to die out without efforts being made to preserve it.' (Fleay 1934: 22). His pleas were not in vain. In January of the following year, the Victorian Government issued a proclamation of a closed season for the whole year for both quoll species (Seebeck 1984). It is interesting that the protection was in the form of a 'no take' closed season, rather than full protection as a threatened species. Seebeck (1984) also mentions early attempts (in 1936) to use camera traps to detect Eastern Quolls near Lake Corangamite, with little success.

Conclusion

The Eastern Quoll is now absent from mainland Australia but was once widespread and prevalent in south-west Victoria. In the late 1800s and early 1900s, quolls preyed on poultry and were shot, poisoned or trapped by landholders. However, quolls were also recognised for their

value in keeping Rabbit numbers in check, especially by preying on young kits. Reasons for the demise of Eastern Quolls in Victoria include disease, persecution by landholders and predation by the introduced domestic/feral Cat and European Red Fox.

The larger Spot-tailed Quoll is fortunately still present in Victoria, but in low numbers in isolated pockets. In western Victoria they are found in Budj Bim, the Grampians and Otway Ranges. It seems in the south-west, Spot-tailed Quolls were never numerous, but they were still reported as widespread.

This research could not have been possible without reports available in old, regional newspapers. Most towns had their own newspaper and larger towns like Warrnambool had two titles. Natural history reports were quite common in these papers and provide a valuable source of important historical information.

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Occurrence of the Southern Purple Azure butterfly *Ogyris genoveva* (Lepidoptera: Lycaenidae) near Melbourne

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Abstract

The occurrence of the Southern Purple Azure butterfly *Ogyris genoveva* (Hewitson, 1853) near Melbourne is reviewed, based on historical records (scientific literature, museum specimens and unpublished observations) and more recent observations. Overall, the species has been recorded from a total of 10 sites representing two discrete populations or metapopulations. Historically, the species was known only from a limited area (c. 80 km^2) 40–50 km west-north-west of Melbourne, but anecdotal records (mostly historical, from 1939–1980) indicate that *O. genoveva* also occurred in a restricted area (c. 50 km^2) in the outer suburbs 25–35 km north-east of Melbourne. The eastern population is probably no longer extant due to the extent of habitat loss, deterioration and fragmentation. The populations of *O. genoveva* near Melbourne appear to be phenotypically distinct and possibly isolated from those to the north of the Great Dividing Range. Field surveys are therefore needed to assess the species' conservation status and management options, and to determine if it still occurs east of Melbourne. (*The Victorian Naturalist* **138**(3), 2021, 85–91)

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Introduction

The Southern Purple Azure *Ogyris genoveva* (Hewitson, 1853) (Fig. 1) is a large, spectacular butterfly of the cosmopolitan family Lycaenidae. It has a broad distribution in south-eastern Australia, from central Queensland, through New South Wales, the ACT and Victoria to eastern South Australia (Braby 2000). It occurs in a variety of woodland habitats in the lower rainfall areas, including the slopes, foothills and inland plains of the Great Dividing Range. The larvae specialise on mistletoes, mainly in the genus *Amyema*, but they also feed on *Dendrophthoe* and *Muellerina* (Loranthaceae) and, like many lycaenids in Australia, are always attended by a specific ant, in this case sugar ants *Camponotus* spp., in a mutualistic relationship. The larvae feed nocturnally, hiding by day under bark, in hollow branches (on the host tree or dead limbs on the ground), or at the base of the host tree in 'ant chambers' under the ground, always in association with large numbers of sugar ants (Burns 1931; Braby 2000; New 2011; Field 2013). Pupae are found in the same situations as the late instar larvae. Near Melbourne (i.e. within c. 50 km of the CBD), the species is univoltine (has one generation per year), with adults flying from late December to early March, with most records in January and February.

Populations of the butterfly occur in highly localised 'colonies'. It is thought that the species, like others in the genus with obligate ant associations, has a metapopulation structure in which each population comprises a series of discrete subunits or subpopulations (colonies) scattered over the landscape, and that these subunits are interconnected by occasional dispersal events. The highly localised occurrence of the species is probably due to the spatially patchy occurrence of suitable combinations of: (1) host trees (typically smooth-barked eucalypts), that (2) support a minimum number of

Fig. 1. *Ogyris genoveva* from Werribee Gorge, Victoria, showing the pronounced sexual dimorphism between the sexes: male (left), and female (right). Note the unusual marking on the forewing upperside of the female, which is characteristic of the population west of Melbourne.

clumps or biomass of the appropriate species of mistletoe, and (3) a relatively high abundance of the attendant ant.

Ogyris genoveva has usually been considered a rare insect, in part due to its highly localised (spatial) distribution, even though individual colonies may comprise hundreds of individuals. This factor, coupled with its brilliant colouration and large size, has rendered the butterfly highly sought-after by collectors. A consequence of this is that, when biologists discover colonies, great secrecy may surround their exact location in order to reduce the impact of unscrupulous collectors. A contributing factor to this rarity is that the distribution of *O. genoveva* in Victoria is now highly fragmented due to extensive land-clearing practices (Britton *et al.* 1995; Gullan *et al.* 1996; Braby 2000; Field 2013). Near Melbourne, concerns that several sites had been extirpated (Britton *et al.* 1995; Braby 2000) led to the taxon *O. genoveva araxes* Waterhouse & Lyell, 1914 being listed as Vulnerable under the *Flora and Fauna Guarantee Act 1988*. However, while some populations (e.g. near Melbourne) may be threatened, Sands and New (2002) considered the subspecies *O. genoveva araxes* as a whole to be of no conservation significance for Victoria. Nevertheless, it is a species that needs to be closely monitored given that it may be susceptible to habitat fragmentation, particularly in landscapes with limited habitat connectivity between isolated patches (New 2011). Although the species has been well-known from areas to the west of Melbourne (e.g. McCubbin 1971), my investigations over the past 33 years have revealed that a previously unknown population of *O. genoveva* also formerly occurred to the east of Melbourne. The purpose of this paper is to review the occurrence of the species near Melbourne, based on the scientific literature, museum specimens and unpublished observations, and to document the occurrence of *O. genoveva* east of Melbourne for the first time.

The following acronyms refer to repositories where specimens have been examined: MV, Museums Victoria, Melbourne; AM, Australian Museum, Sydney; ANIC, Australian National Insect Collection, Canberra. Geo-coordinates (latitude and longitude) for each site were determined by Google Earth or the aid of a portable GPS unit (using WGS84 datum), converted to decimal degrees, and then plotted in ArcGIS version 10.7.1 using a projected coordinate system (GDA94_MGA_zone 55).

Taxonomy

Common and Waterhouse (1972, 1981) placed the population west of Melbourne under the subspecies *O. genoveva araxes* (Waterhouse & Lyell, 1914), the type locality of which is Dimboola in western Victoria. This taxonomic assignment appears to have been based on an earlier comment by Waterhouse (1941: 237) who stated that ssp. *araxes* '... is the Victorian race typically from Dimboola ... Specimens from Horsham agree with this as no doubt do

those from Melbourne, which I have not yet seen.' However, Dunn and Dunn (1991) and Braby (2000) did not recognise this subspecies due to the extent of variation within and between populations across the geographical range of the species. However, the Melbourne population appears to be distinct. Of 130 females examined in museum collections, just over one-third (35%) were found to have a small pinkish-cream spot at the end of the discal cell below the broad cream subapical patch on the upperside of the forewing (Fig. 1). I have not seen this marking in specimens from elsewhere across the broad geographical range of the species, and it appears to be unique to the Melbourne population. The character was also clearly illustrated in the painting by McCubbin (1971:76). This character alone is probably not sufficient to warrant subspecific status, but it does highlight the phenotypic uniqueness of the population near Melbourne, and suggests that this population south of the Great Dividing Range may have been isolated for a considerable period from the nearest population (Broadford–Tallarook), which lies to the north of the Kilmore Gap in the Great Divide. Phylogeographic studies of *O. genoveva*, which included limited samples from Victoria (Werribee Gorge, Avenel near Seymour, and Alpine National Park), suggest negligible genetic differentiation within the species (Schmidt 2007).

Records west of Melbourne

Historical records of *O. genoveva* west of Melbourne are from Bacchus Marsh and Melton (McCubbin 1971; Common and Waterhouse 1972, 1981), approximately 40–45 km west-north-west of the CBD (Fig. 2). The Bacchus Marsh record was based on two historical specimens (probably c.1940): a single female specimen in MV (LEP17684) labelled 'Bacchus Marsh, Mr Slach', 'J.A. Kershaw Collection, PURCH. June 1941'; and a male specimen in the AM labelled 'Bacchus Marsh' that is undated. The female is in worn condition and presumably was collected as an adult and not reared from the immature stage. Records from Melton refer to a subpopulation along 'Melton Gorge' (Djerriwarrh Creek) in Long Forest Nature Conservation Reserve (Braby 2000) from which about 300 specimens were sampled over a 30-year period, 1941–1971. The earliest specimens from this site, dating back to 1941/1942, were collected by JC Le Souëf and FE Wilson—presumably they were the first entomologists to discover the colony—and the last specimens (five males) were reared in 1971 by WNB Quick. Two other historical records are from Coimadai, based on a small series of specimens (six males, three females) in the ANIC, reared in 1971 by WNB Quick, and Djerriwarrh Creek near Coimadai, based on a single specimen (a female) in the ANIC, collected in January 1976 by WNB Quick. The colony at Melton Gorge was well known to many entomologists last century, including JC Le Souëf, FE Wilson, AN Burns, WNB Quick, DF Crosby, J Landy and C McCubbin, but it is not entirely clear where Quick discovered the breeding colony at Coimadai. The small township of Coimadai is located near Lerderderg Gorge, approximately 10 km north-west of Melton Gorge, although the Coimadai Creek flows south through Long Forest Nature Conservation Reserve parallel to, and west of, Djerriwarrh Creek. This site is considered to be separate from Quick's subsequent record from 'Djerriwarrh Ck, nr Coimadai' because of the different labelling of the location data.

The colony at Melton Gorge occurred on a slope with a western aspect just east of Djerriwarrh Creek, and consisted of about six large smooth-barked gums (most likely Yellow Gum *Eucalyptus leucoxylon*) on which grew clumps of the mistletoe food plant (*Amyema* sp.) (DF Crosby, pers. comm. 2020). The immature stages also occupied several large dead hollow branches near the base of the host trees in which the *Camponotus* ant colonies lived. DF Crosby (pers. comm. 2003) recalls that the core host trees on which the species bred consisted of trees rather than mallees (Bull Mallee *Eucalyptus behriana*), although McCubbin (1971:78) noted finding larvae and pupae at the bottom of a hollow limb near the base of a 'mallee gum'. The early collectors were aware of the precarious nature of the colony and they rationed themselves to three or four pupae each season unless they were abundant, which happened every four to five years. Thus, sustainable 'harvesting' of the butterfly was achieved by carefully removing the bark to expose the final instar larvae and pupae, and then very carefully

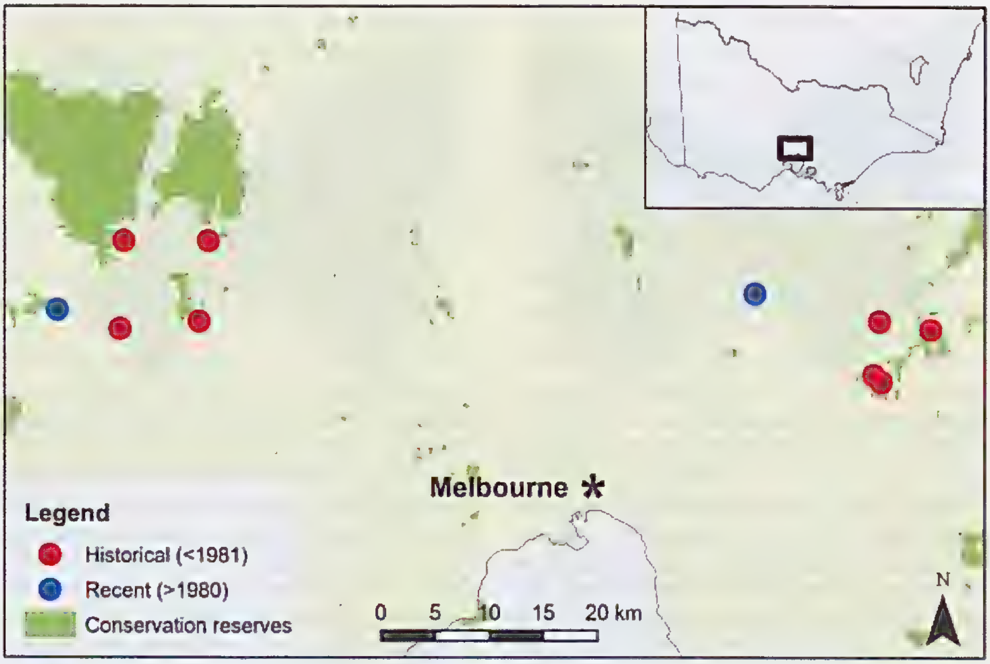

Fig. 2. Distribution map of *Ogyris genoveva* near Melbourne, showing the two populations based on historical and recent records of the species.

placing the bark back in its exact original place fixed with wire. However, this practice was not always carried out, and the colony declined during the 1970s due to excessive disturbance to the ant colonies by some collectors (DF Crosby, pers. comm. 2003, 2020). Subsequently, the butterfly disappeared from the site.

The loss of the butterfly from the Melton Gorge site and absence of recent material from the three other historical sites raised conservation concerns and led Britton *et al.* (1995) to postulate that the population west of Melbourne may be extirpated. However, since that time, in 2003–2004 I discovered the species breeding in eucalypt woodland at Werribee Gorge west of Bacchus Marsh, approximately 50 km west-north-west of Melbourne (Fig. 3). At this site, a total of 28 larvae and a number of pupae (not counted, but estimated to be >10) were found associated with Box Mistletoe *Amyema miquelii* parasitising four separate trees of *Eucalyptus leucoxylon* and attended by *Camponotus nigriceps* ants.

Records east of Melbourne

In January 1939, C McCubbin (pers. comm. 2002) recalled capturing a female *O. genoveva* at Warrandyte during the school summer holidays when he was a boy. The specimen was sitting still, close to the ground on the trunk of a eucalypt, and was freshly emerged. The site from which it was collected was located about 'half a mile' upstream of the Yarra River crossing (Kangaroo Ground–Warrandyte Rd) in bushland with a northerly aspect south of the river. Unfortunately, the specimen no longer exists, being destroyed by museum beetles (*Anthrenus* sp.). Presumably, McCubbin had discovered a breeding colony, given the condition and behaviour of the female, which, by his description, would have been located close to the Ringwood–Warrandyte Rd, most likely in the vicinity of Scotchmans Hill Bushland Reserve (in Warrandyte State Park), below which there is a north-to-northeast facing hillslope that leads down to the Yarra River, approximately 29 km east-north-east of Melbourne.

Fig. 3. Yellow Gum woodland habitat of *Ogyris genoveva* at Werribee Gorge, Victoria, showing host tree *Eucalyptus leucoxylon* and larval food plant Box Mistletoe *Amyema miquelii*. Insert figure shows a final instar larva with attendant ants *Camponotus nigriceps*.

AN Burns subsequently made a second record of the species at Warrandyte during the late 1940s, but few details were provided at the time, reflecting the secrecy surrounding extant sites noted earlier, and the colony was never relocated (DF Crosby, pers. comm. 1987). I therefore contacted Burns to see if he could elaborate on his finding. On 22 March 1988 he replied to my letter and stated:

> My record of *O. genoveva* was on a couple of trees with *A. miquelii*, I think my memory still serves me right—there were only 3 larvae which I left severely alone, the spot was on the right hand side of the track on a slight hillside within I would say 500 yards [of] where the road turns right, one branch crossing the Yarra bridge [Kangaroo Ground–Warrandyte Rd], the other branch going directly opposite.

Burns' breeding record clearly places the site on the Research–Warrandyte Rd, most likely in the vicinity of Browns Rd, where the main road follows a ridge, below which is a hillslope with a west-to-northwest aspect that leads down to the Yarra River, directly east of Pound Bend Reserve, Warrandyte State Park. This site is located on the north side of the river approximately 1 km north-west of McCubbin's site.

I am aware of at least three records of *O. genoveva* from Kangaroo Ground. In January 1966, F Douglas (pers. comm. 1988) recalls observing a very large male *Ogyris* flying rapidly in the eucalypt canopy on a ridge along Henley Road, Bend of Isles (c. 1 km north-west from Skyline Rd), approximately 35 km east-north-east of Melbourne. The specimen was substantially larger than the Broad-margined Azure *O. olane* Hewitson, 1862 and Dark Purple Azure *O. abrota* Westwood, 1851, the only other *Ogyris* spp. which occur in the area, and it was almost certainly *O. genoveva*.

A male *O. genoveva* was captured from Kangaroo Ground Memorial Tower (c. 31 km east-north-east of Melbourne during the early 1970s by J Temby (pers. comm. 1987). The specimen was slightly worn, and it was collected when weather conditions were very hot. Unfortunately, the specimen no longer exists, having been destroyed by insect pests. Subsequently, about three to five large male *Ogyris* were observed flying at the same site on a single occasion in January 1980 (T Brain and A Kimpton, pers. comm. 1987). The butterflies were larger, and flew more powerfully, than *O. olane*, which regularly flies at Kangaroo Ground Memorial Tower. Although no specimens were captured, they were almost certainly *O. genoveva*. Kangaroo Ground Memorial Tower is surrounded by cleared agricultural land; however, it is situated at the top of a prominent hill and many butterflies use the area as a hilltopping site for mate-location.

A more recent record of *O. genoveva* from the outer north-eastern suburbs of Melbourne is from the Plenty River Gorge (Yellow Gum Park), approximately 24 km north-east of Melbourne. On 21 December 1990, Beardsell (1997, and pers. comm. 1993) observed a single female on a ridge during mid-to-late afternoon. The habitat below the ridge consists of dry woodland dominated by *Eucalyptus leucoxylon* and Yellow Box *E. melliodora* on a hillslope with a western aspect above the river.

Discussion

A review of distribution records of *Ogyris genoveva* near Melbourne indicates that this species has been recorded from at least 10 sites representing two populations (metapopulations), one east and one west of Melbourne (Fig. 2). Regarding the eastern population, anecdotal records indicate that the species has been recorded from at least five sites, on six occasions. All sites of the eastern population are located within 35 km of the outer north-eastern suburbs of the CBD, and most records are historical (i.e. before 1981). There are currently no voucher specimens or other evidence, such as photographs, to substantiate these records even though at least two specimens were collected in the historical past, but all records were made by experienced and reliable lepidopterists/naturalists. One record concerns the immature stages, providing evidence of breeding. All sites are located within a restricted patch of dry eucalypt (Box, or Box-ironbark) woodland of low topographic relief, similar to the Victorian Central Goldfields, and they were probably part of a single metapopulation originally distributed over an area of at least 50 km^2 (based on the minimum convex polygon of the five known sites). Rainfall for this area is relatively low, with the mean annual rainfall varying from approximately 650–750 mm. Presumably, the species formerly occurred in the Eltham–Greensborough district, which lies within the known extent of occurrence (between the Plenty and Warrandyte sites), before that area was extensively urbanised by housing development. Indeed, KV Hateley (pers. comm. 1987) understood that a colony of *O. genoveva* was located in the Eltham district by FE Wilson, but I have not found any evidence to support this supposition.

It is considered unlikely that the population east of Melbourne is still extant due to the extent of habitat loss, deterioration and fragmentation. The historical breeding sites at Warrandyte have long since been extirpated; although both sites are still vegetated, they have been developed for residential and rural housing blocks and the habitats now comprise degraded box eucalypt woodland. The historical males recorded hilltopping at Kangaroo Ground Memorial Tower probably originated from breeding colonies in remnant bushland to the south at Kangaroo Ground (near the Yarra River), North Warrandyte or Research. Despite targeted searches at this site by others, including T Brain, F Douglas and myself during the 1980s and 1990s, the species was not detected. Limited searches for *O. genoveva* at Plenty River Gorge by C Beardsell and myself during the 1990s and 2000s failed to locate breeding colonies, although the co-occurrence of host trees (*Eucalyptus leucoxylon* and *E. melliodora*), mistletoe food plants (*Amyema miquelii*) and attendant ants (*Camponotus nigriceps*) suggests the habitat is highly suitable. Indeed, that habitat in which the adult was observed at Plenty Gorge is very similar in terms of vegetation structure and plant composition to the breeding habitat at Melton Gorge (Long Forest) and Werribee Gorge (Fig. 3).

The longevity or temporal duration of colonies/sites of *O. genoveva*, and indeed all other Australian myrmecophilous lycaenids that comprise a metapopulation structure, is poorly known. The area of occupancy of a breeding site of *O. genoveva* appears to be variable—a colony may comprise a single host tree (with one or more mistletoe clumps) or a number of host trees distributed over a much larger area. Long-term observations of *O. genoveva* at Lake Hindmarsh, Victoria, indicate a site occupancy of at least 33 years (1987–2020) (F Douglas, pers. comm. 2020), and the data reported herein for Melton indicate a minimum site occupancy of 30 years (1941–1971). Braby (2011) noted that a colony of the Imperial Hairstreak *Jalmenus evagoras* near Melbourne persisted for more than 20 years, and that a colony of the Fiery Copper *Paralucia pyrodiscus* in Castlemaine, Victoria, was still extant after 110 years, indicating that site occupancy may persist for over a century for some lycaenid species. In a metapopulation system, sites eventually die out (e.g. due to death of host trees, larval food plants or ant colonies) but these local losses are balanced by the colonisation of new sites or recolonisation of former, unoccupied sites so that the population remains in equilibrium (New 1993; New *et al.* 1995).

The eastern population of *O. genoveva* lies just over 50 km east of the population west of Melbourne, but the extent to which the two populations were interconnected may never be known. The western population probably

comprised a single metapopulation originally distributed over an area of approximately 80 km^2 based on the minimum convex polygon of the five known sites, but it is now highly fragmented and substantially reduced in its extent of occurrence.

Field surveys are urgently required to determine if *O. genoveva* is still established east of Melbourne. The most likely location where colonies might persist is Plenty Gorge, which preserves a relatively small patch (c. 1000 ha) of Box-ironbark woodland along the escarpments and river gorge (Beardsell 1997) that is part of the larger Plenty Gorge Parklands, a conservation reserve managed by Parks Victoria. However, the perimeter of Plenty Gorge has been heavily impacted by urbanisation in recent decades, and the gorge was extensively burnt by wildfire in early 2020. Moreover, the area is now isolated from nearby remnant bushland reserves with minimal corridors. The putative metapopulation structure of *O. genoveva* implies that connectivity between subunits or subpopulations (breeding colonies) over large areas is critical, and the progressive loss of these subpopulations over the past 80 years due to urbanisation (particularly habitat loss, degradation and fragmentation) may have led to the local demise of this interesting butterfly. In other words, once the number of subunits fell below a critical threshold and breeding colonies became isolated because linkages between them were disrupted (i.e. adult dispersal between subunits was no longer possible due to lack of suitable corridors), the metapopulation was no longer viable.

Surveys are also required to ascertain if the species is still extant in Long Forest Nature Conservation Reserve (Britton *et al.* 1995). Although relatively small in extent, Long Forest (c. 800 ha) is well known for its rich and unusual flora and fauna, preserving an isolated patch of dry mallee woodland, and is thus highly significant for biodiversity conservation (Friends of Werribee Gorge and Long Forest Mallee Inc. 2002; Hewish *et al.* 2006). The area was historically significant for *O. genoveva*, and for the entomologists who took great pride in the conservation (sustainable collection) of the species, but the last confirmed record was 50 years ago.

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Death of a butterfly: Splendid Ochre *Trapezites symmomus soma*

On 2 February 2021, I was delighted to see a Splendid Ochre butterfly *Trapezites symmomus soma* perched on a leaf of a dwarf bean plant in our garden (see front cover) in the Melbourne suburb of Notting Hill. This was the first time I had seen this species here. It stayed on the bean leaf for at least an hour after I first noticed it.

On 28 February, I came across a Splendid Ochre—possibly the same one—in less fortunate circumstances. I had taken a pair of bed sheets from my linen cupboard and, on putting the bottom sheet in place, was surprised to see a dark greyish patch of what looked like dust on it. Then I saw that a dead Splendid Ochre had fallen from the sheet and was lying on the floor. So this butterfly must have settled on the sheet, which had been folded in half on the clothesline, on about 16 February. Insects perched on washing usually escape as soon as they are disturbed by the unpegging process, but obviously this one had not been dislodged. I tried to console myself by thinking that it may have been nearing the end of its lifespan anyway, and hoped it had reproduced before its life ended.

Fig. 1. Upper surface of dead Splendid Ochre.

Fig. 2. Lower surface of dead Splendid Ochre.

I photographed the upper and lower surfaces of the butterfly (Figs 1 and 2), then put it on a damp paper towel in a plastic container for a few hours. This procedure enabled me to manoeuvre its wings without breaking them, in order to measure the wingspan, which was only 30 mm in the 'dried' position but approximately 53 mm when the wings were stretched out.

The Splendid Ochre is also known as the Symmomus Skipper (Braby 2005) or Symmomus Rush-skipper (Butterfly Conservation SA [BCSA] website 2021), and belongs in the family Hesperiidae. There are three subspecies: *Trapezites symmomus sombra* lives in the tablelands of North Queensland; *T. symmomus symmomus* in southern Queensland and New South Wales; and *T. symmomus soma* in Victoria and South Australia. In Victoria and South Australia, it flies during January, February and March (Braby 2005; BCSA website 2021). According to the BCSA website (2021), it is 'usually not very timid and can be approached with care when settled'; this concurs with my observations. I didn't see it flying, but its flight is described as rapid and usually close to the ground during sunshine (Braby 2005). Its larvae feed on *Lomandra* spp., especially *L. longifolia*. Numerous *L. longifolia* plants are growing only a few hundred metres from here, and may account for the butterfly's presence.

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Henry Watts (1828–1889): 'the pioneer of freshwater phycology in Victoria'

Henry Watts was a microscopist, botanist, marine biologist and a manufacturer of perfumes made from distilling flowers. Before this latter occupation, he was a bootmaker. The first record we have of Watts was his setting up a bootmaking shop in Warrnambool in 1858 and, in the same year, giving a lecture to the Warrnambool Mechanics Institute on 'The Microscope'. In regard to Watts' lecture, O'Callaghan (2006: 43) wrote:

> Watts had apparently purchased four microscopic photographs from overseas which were no larger than a pin head, but when put under the microscope, revealed such items as the nine members of the Imperial Family of Russia and a tablet four feet long containing 755 letters, every one of which could be read clearly.

Watts was an avid collector of small specimens that he found in fresh and sea water along the coast of Warrnambool. He seemed especially interested in microscopic organisms such as diatoms, and in December 1859 wrote as follows to Professor Quekett of London (Fig. 1):

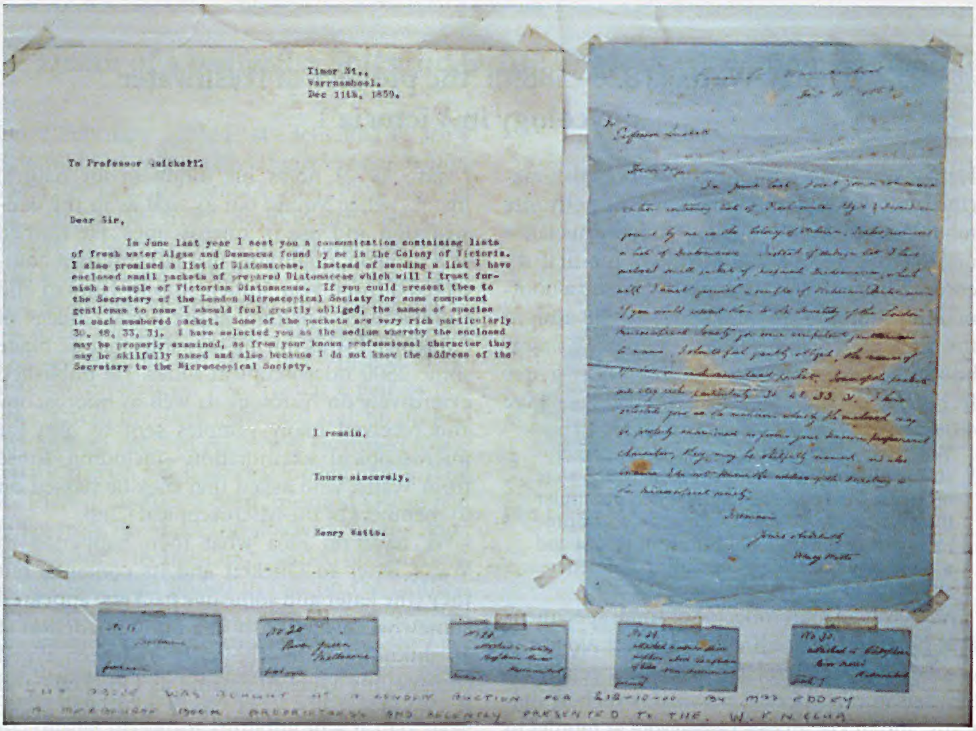
> To Professor Quekett
> Dear Sir,
> In June last year I sent you a communication containing lists of fresh water Algae and Desmocea found by me in the Colony of Victoria. I also promised a list of Diatomaceae. Instead of sending a list I have enclosed small packets of prepared Diatomaceae which will I trust furnish a sample of Victorian Diatomaceae. If you could present them to the Secretary of the London Microscopical Society for some competent gentleman to name I should feel greatly obliged, the names of species in each numbered packet. Some of the packets are very rich particularly 30, 48, 33, 31. I have selected you as the medium whereby the enclosed may be properly examined, as from your known professional character they may be skillfully named and also because I do not know the address of the Secretary of the Microscopical Society.
> I remain,
> Yours sincerely, Henry Watts

At the time, John Thomas Quekett (1815–1861) was regarded as one of the world's leading microscopists. The Quekett Microscopical Club was established in 1865 in his honour and continues today. A biography of Quekett (Anon 1972) notes his fondness for natural history when young but as well as in the construction and use of microscopes. He trained as a surgeon, qualifying in 1840 and then completed a three-year studentship in Human and Comparative Anatomy at the Royal College of Surgeons. It was during this stint that he made some 2500 microscopical slides. He published extensively on histology as well as microscopy and received many samples sent to him for microscopical examination—including those from Watts, who asked that they be passed on to members of the Microscopical Club.

We have no idea what then happened to Watts' letter to Quekett and its contents, but they (the letter and some five packets) appeared somewhat mysteriously at a London auction at an unknown date. The letter had been typed (misspelling Quekett's name as Quickett) and mounted on stiff card, along with the original letter and the packets of diatoms (Fig. 1). They were purchased for £12 10s by a Miss Eddey who was a 'Melbourne book proprietress' according to the framed artefact; Miss Eddey then donated the objects to the Warrnambool Field Naturalists Club at a meeting in 1976 via Mr Beaton. In 2005, the material was donated to the Warrnambool and District Historical Society (Heathcote 2008). We plan to have the diatoms examined by experts and report on the findings in due course.

But what else do we know of Mr Henry Watts? O'Callaghan (2006) noted that Watts investigated the guano in Warrnambool's Starlight bat cave, expecting to find microscopic algae but instead, not surprisingly, found arthropod skeletal remains. We also know that in 1861 he sent a collection of more than 100 seaweeds for an exhibition in Melbourne. This was a momentous occasion and the catalogue was prefaced by Baron Sir Ferdinand von Mueller and Professor Frederick McCoy (among others) (Government of the Colony of Victoria 1861).

The *Examiner*, Warrnambool's local newspaper, was very excited by his work, noting it was 'really refreshing in these degenerate days



Timor St.,
Warrnambool.
Dec 11th, 1859.

To Professor Quickett

Dear Sir,

In June last year I sent you a communication containing lists of fresh water Algae and [illegible] found by me in the Colony of Victoria. I also promised a list of Diatomaceae. Instead of sending a list I have enclosed small packets of prepared Diatomaceae which will I trust furnish a sample of Victorian Diatomaceae. If you could present them to the Secretary of the London Microscopical Society for some competent gentleman to name I should feel greatly obliged, the names of species in each numbered packet. Some of the packets are very rich particularly 30, 18, 33, 31. I have selected you as the medium whereby the enclosed may be properly examined, as from your known professional character they may be skilfully named and also because I do not know the address of the Secretary to the Microscopical Society.

I remain,

Yours sincerely,

Henry Watts.

Fig. 1. The framed letter from Watts to Quekett (and a typed version of it) and five packets of diatoms. Item 000185, collection of the Warrnambool and District Historical Society Inc. in Victorian Collections.

to find someone with a soul elevated above mere worldly gain' (O'Callaghan 2006: 43). Watts made further contributions to the study of algae by reading a paper entitled 'Fresh water algae of Victoria' at a meeting of the Royal Society of Victoria (RSV) in Melbourne in 1862 and a year later exhibited fossil polyzoa (now called bryozoa or ectoprocta) at an RSV meeting. In 1863, the *Examiner* also noted that Watts had been made an honorary corresponding member of the Bristol Microscopical Society (O'Callaghan 2006).

Watts and his perfumes

Henry Watts was also very interested in flowers and in 1864 his exhibit at the Warrnambool Horticultural Society Show, of a water plant in flower, generated much interest. His love of flowers spurred him to change occupations from bootmaking to growing flowers for sale from his home in Warrnambool. He then moved into making perfumes, including his 'Warrnambool Posy', which he sold for two shillings: 'a delicious perfume for the handkerchief'. In 1865 Watts won prizes for his perfumes at the annual Spring Exhibition of the Horticultural Society of Victoria and again at the Ballarat Horticultural Society Show in 1866, where jurors commented that his perfumes were 'superior to the greater portion of the imported perfumers' (O'Callaghan 2006: 44). In the same year he showed 44 perfumes at Melbourne, displayed in a cabinet made by Stelling Bros, Warrnambool. But he had not forgotten his seaweeds and sent these and microscopical specimens to the 1866 Melbourne Exhibition.

The correspondent at *The Leader* newspaper was glowing in praise of Watts' perfumes (Anon 1866a: 7):

> Another exhibitor is Mr Henry Watts, of Warrnambool. His attention is devoted almost exclusively to the manufacture of perfumes — and with so much success that his products are growing into great favour, and may very shortly be expected to render any importations of ordinary, perfumes almost unnecessary. Their fragrance, particularly the Dagmar Bouquet is exceedingly powerful, and most agreeable, and they are placed in the market at a figure which

> will, with a superior article, enable him to compete with English or French importations.

Watts certainly captured the interest of *The Australasian*'s correspondent during the Exhibition. The paper subsequently noted (Anon 1866b: 7) that Watts was Victoria's only regular manufacturer and trader in perfumes and that at the Exhibition he gave samples freely to ladies who 'are thus carrying away with them from the Exhibition evidences of his success'. This was followed by a detailed description on how the perfumes were made, stressing the care Watts devoted to using flowers with delicate colours, like roses and wattles. Here he

> adopts a more elaborate and searching system, by means of maceration. The flowers are placed in oil thirty or forty hours, and after pressure, replaced by other flowers till the oil is full of the required colour. Pure Warrenheip spirit is then mixed with the oil till it is charged with the colour, and a simple extract forms the scent. As might be expected, Mr Watts makes the extract of the wattle the basis of them all. The material is abundant at Warrnambool, and during the flowering season as many as twenty boys are engaged gathering the blossoms for 6d per lb.

The article also notes the many awards Watts had received for his perfumes, including a £50 grant to help establish his business. O'Callaghan (2006: 44) indicates this was from the Victorian New Industry Commission that noted Watts was

> employing himself, his wife and child in the perfumery venture and that he also employed children to gather blackwood and wattle blossom from the surrounding bush.

Watts must have also exhibited his previously mentioned polyzoa and apparently agreed to a request by the Director of the National Museum to donate the collection to that institution. Watts' perfumes also generated a humorous article in the *Melbourne Punch* that noted (Anon 1865: 2):

> MR. HENRY WATTS, of Warrnambool, has introduced a new industry, by making perfumes from native flowers. He has made experiments upon the flowers of rhetoric of some of our Victorian orators, but, as he found they contained no scents (sense) whatever, he does not intend to investigate them any further.

Watt's contributions to science

Watts was an active member of the Field Naturalists Club of Victoria from its inception. He was the Club's first librarian, from 1881–82, then its Vice-President for one year, and a member of the Club's Committee for a further year (Anon 1890). He also published in the first volume of *The Victorian Naturalist* (Maiden 1908), eventually writing a further three papers for the Club's journal over the next three years.

Whilst Watts' published works were somewhat modest, with only six papers published (see Appendix), his contributions to science were nevertheless important, especially in terms of some significant collections of algae. Watts collected marine and freshwater algae from around Warrnambool, and later collected freshwater algae from Ballarat and aquatic environments in the Yarra River basin. The marine algal specimens were sent to Dublin University's Professor William Henry Harvey, and the freshwater algae to Ferdinand von Mueller, who passed them on to Friedrich Kutzing and C F Otto for identification (Wikipedia 2019). Furthermore, von Mueller named a species of wattle after him (*Acacia wattsiana*) and Harvey named two algal species in his honour—*Wrangelia wattsii* and *Crouania wattsii*. Harvey included the marine algae sent to him by Watts in his *Phycologia australica* (1858–1863).

Harvey met von Mueller when he visited Melbourne in the spring of 1854 and in early summer of that year collected seaweeds along the Victorian coastline from Phillip Island to Port Fairy (Willis 1990). It is not known whether Watts actually met Harvey in 1854 as it is uncertain where Watts was living at the time. Nevertheless, the fact that Watts sent the specimens to Harvey directly (rather than via von Mueller) suggests that Watts possibly knew Harvey personally.

Despite Watts being described as the 'pioneer of freshwater phycology in Victoria', by Entwisle (1990), that same author has noted Watts' work had some severe limitations. These included the inability of workers in the field to determine or verify the species; and the loss of many of the materials Watts used. Indeed, most of his specimens were apparently lost while he was ill (Anon 1890) although the National Herbarium of Victoria does possess some dry voucher specimens (Entwisle 1990).

Overall, there was a lack of authorities provided for names of species Watts identified. It seems that while Watts had some freshwater species identified by authorities in the field

(Kützing, Otto, Norstedt), he identified most himself using published accounts from Europe and North America—which Entwisle (1990) considers inappropriate in many cases.

Financial woes

Despite the popularity of his perfumes, Watts failed to generate sufficient income to stave off his creditors, and in 1867 lost his equipment to the Sheriff and was declared bankrupt in the Geelong court (Anon 1867). A year later Watts moved to Melbourne where he set up another perfume distillery (even advertising in Warrnambool for a supplier of *Bursaria spinosa*), but it seems that business also fell apart (O'Callaghan 2006). In 1868 Watts was again mentioned in court, but this time as the innocent buyer of stolen perfume bottles (Anon 1868). Two years later Watts appealed against a court order sending him to gaol as he failed to pay his wife maintenance of 15 shillings a week following their separation. The appeal was upheld on the grounds Watts genuinely could not pay the sum, although costs of £3 3s were awarded against him (Anon 1870).

Watts was eventually discharged from insolvency in 1873 (Anon 1873).

Later life

Henry Watts spent the final year of his life (1889) in the Yarra Bend Lunatic Asylum, suffering from dementia and paralysis. Following his death in 1889, an obituary was published in *The Victorian Naturalist* (Anon 1890). It mentions that, in his later years, he spent much time microscopically examining botanical, zoological and geological materials and had accumulated a large quantity of specimens and slides. As mentioned above, when he became increasingly ill many of these materials were lost—a great pity as they may well have proved useful for examination by later scientists and naturalists.

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(1884) On a species of freshwater algae from near Berwick. *The Victorian Naturalist* **1**, 21.

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